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CANADA

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Correlation between the quantity and quality of the gonads in the Baltic cod

by L.A. Shapiro (Sector of Fish Physiology and Protection of the Marine Environment, BaltNIIRKh)

The Baltic cod found on the outskirts of its range of distribution has a number of specific characteristics which ensure the best quality of roe. As a result of our investigation, we established a correlation between the physiological condition of females of different age and the quality and quantity of the roe produced by them. It has been established that the energy of oogenesis in cod of the eastern part of the Baltic Sea is higher than in other geographic areas. Individual and populational fecundity, as well as the generative production of females during different years are assessed here.

At the present time, when the level of exploitation of the Baltic cod approximates the threshold level, it has become much more important to study the various aspects of its population dynamics. The purpose of this is to ensure a stable supply of fish for the fishing industry, and to organize an efficient and biologically sound economy. In order to establish the tendencies of the recruitment of commercial species of fish, we must also gain some knowledge of the initial stages of reproduction by studying both the quantity and quality of gonad output. However, whereas the quality of the roe (which depends on the conditions of existence and physiological state of the brood stock) affects the progeny directly [5; 17; 23], the effect of quantity is indirectly related to the survival rate, and acts as an adaptation called upon to alter the magnitude of recruitment when specific conditions of existence undergo change [8; 11; 14; 15]. The cod belongs to the fishes with an asynchronous type of oocyte growth, which deposit their eggs in portions, or batches. Several separate groups of oocytes form in the gonads of such fish, and from these, batches of eggs form [8; 25]. These batches are not equal in quality. The most viable larvae hatch out from the first batches of eggs [16].

The formation of gonads requires a great deal of energy and plasticity, and a fairly long period of time. The generative processes associated with this are already initiated in winter, during the growing period, when we begin to encounter individuals with gonads at the third

stage of maturity in the catches. The quantity of roe deposited in the process of spawning amounts to 25-30% of body mass and more.

A fair amount of attention has been devoted to the study of fecundity in different cod populations. However, notwithstanding their indisputable importance, these studies were limited mainly to the analysis of absolute individual fecundity (AIF) and its dependence on the mass, length and age of the females. A number of papers have been devoted to the population fecundity of cods, specifically the Barents Sea cod and the North Sea haddock [1; 20]. The literature contains practically no data on the Baltic cod, except for a number of comments concerning the relationship between fecundity and generative metabolism [9; 19; 21]. This being the case, the purpose of this particular study was 1) to trace the correlation between the physiological condition of the females of this species and the quality and quantity of the roe produced by them, and 2) to assess the individual and population fecundity and the generative production of the females of the Baltic cod.

Material and method

The material used in this study was collected during trips to the eastern part of the Baltic Sea. Female specimens of the cod were taken from survey trawl catches during the spawning periods of 1976-1978, 1983 and 1984. Each individual was subjected to standard biological analysis, which included determination of body size and weight, the weight of the gonads and liver, the stage of gonadal maturity, and age. Fecundity was determined by counting the number of eggs in a weighed portion of roe fixed with 4% isotonic Formalin, and then expressing it in terms of gonadal mass. Proceeding from the data on absolute individual fecundity (AIF), we calculated the relative individual fecundity (RIF), the weighted average number of eggs per sexually mature female [7], and then populational fecundity, the number of eggs deposited by the entire population of the Baltic cod [2]. At the same time, we determined the lipid content in the tissues of the females by Folch's method [26], and the protein content by Lowry's method [24]. The energy equivalent of the roe was calculated as the sum of the energy contained in the lipids and proteins.

Results and discussion

In the process of our study, we established that, depending on the mass of the females, the AIF varies from 200,000 to 2.000,000 eggs on the average. We examined the relationship between the AIF and the mass of the females, and derived equations of linear regression for the following three most important age groups of the Baltic cod:

for females of age (3+) 4 years, F=926.03W-82169.62;

for females of age (4+) 5 years, F=800.3W+103237.9;

for females of age (5+) 6 years, F=1576W-948467.6

Table 1. Equation of linear regression for AIF/body weight ratio, based on our own data and the literature [25]

Author	Populations	Function
Our data		
age	Eastern Baltic Sea	
(3+) 4 years		F=926W-82170
(4+) 5 years		F=800W+103238
(5+) 6 years		F=1576W-948468
Powles, 1958	Gulf of St. Lawrence	$F=0.0026\ (\frac{W}{0.0105})\ 1.55$
May, 1967	Labrador	
	Newfoundland	$F=0.5\ (\frac{W}{0.0105})\ 1.14$
Botros, 1962	Norway	F=790W-41600
	W Baltic	F=860W-297000
Joakimsson, 1969	Iceland	F=519W
Shopka, 1971	Iceland	F=584W-832000
	North Sea	F=526W-948000
	W Baltic	F=746W+95000
Oosthuizen et Daan, 1974	North Sea	F=569W-807000

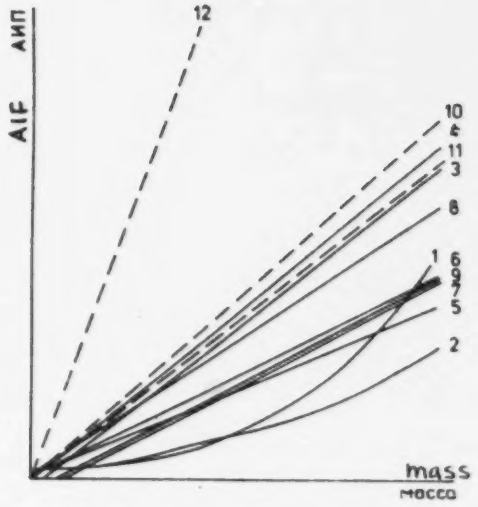

Fig. 1. Graph of equations of linear regression for AIF/body mass ratio in the Baltic cod (based on the literature [25] and our own data):
1 - Gulf of St. Lawrence; 2 - Labrador, Newfoundland; 3 - Norway; 4 - W Baltic; 5 - Iceland; 6 - Iceland; 7 - North Sea; 8 - W Baltic; 9 - North Sea; 10-12 - E Baltic

By comparing the above equations with those in the literature [25], we found that with an increase in the mass of the females, the growth of fecundity in the cods of the eastern part of the Baltic Sea was greater than in other cod populations (table 1; Fig. 1). This enables the E Baltic cod to produce a much larger quantity of roe per gram of body weight, i.e. its RIF is higher than in the cod of other geographic regions. M.P. Bogoyavlenskaya [4] has shown that the specific content of lipids in the liver of Baltic Sea cod is significantly higher than in North Sea cod. This indicates that the processes of oogenesis require greater energy under the variable conditions on the outskirts of the species range.

The Baltic Sea cod, which has a maximum life span of about 10 years, usually joins the brood stock in the third-fourth year of life, and greatly influences the spawning portion of the population up to the age of 7-8 years, participating in 3-5 spawning seasons, depending on physiological condition [10].

Sexual maturity sets in when a certain level of reserve substances has accumulated in the body. In fish joining the brood stock at the age of (2+) 3 years with a smaller body mass than in fish maturing at age (3+) 4 years, the development of the generative tissue is effected by a smaller reserve of energy and plastic substances. For example, the

body's lipid reserve and specific energy content in these fish are lower by15% and 48% respectively. Because of this, the third-year fish produce 28% fewer eggs per gram of body mass without the viscera (tables 2 and 3).

Table 2. Age dynamics of fecundity in Baltic Sea cod

Indices	(2+) 3	(3+) 4	(4+) 5	(5+) 6	(6+) 7	(7+) 8
AIF, no. of eggs	202,776	679,176	936,078	1,312,087	2,178,679	1,391,355
RIF, eggs/g	579	803	852	837	803	506
AIF increment in one year, %	-	+70	+30	+30	+40	-36
RIF increment in one year, %	-	+28	+6	-2	-4	-37
n	3	14	28	16	7	4

Fig. 3. Age dynamics of physiologic-biochemical characteristics in females of the Baltic cod

Indices	(2+) 3	(3+) 4	(4+) 5	(5+) 6	(6+) 7
Hepatosomatic index, %	5.4	7.9	9.6	9.4	8.1
Content of lipids in liver, mg/g	377	407	444	440	429
Reserve of lipids in body, g/kg	33	39	44	44	35
Spec. energy content in gonads, J/g	1.67	3.22	3.11	2.87	2.81
Protein content in gonads, mg/g	69	140	140	127	119

As we can see from the above data, the AIF increases up to the age of (6+) 7 years as the mass of the females increases; after that, an abrupt decrease (by 36%) is noted. A somewhat different picture is observed in the dynamics of the RIF. The maximum quantity of roe per gram of body mass without the viscera is formed in (4+) 5-year-old individuals; at the same time, the first signs of a stressed reproductive system due apparently to age changes in metabolism are noted long before the

decrease in AIF, at the age of (5+) 6 years. At this time, the synthetic processes in the gonads become less intense (the protein content diminishes), and the specific energy content also decreases, which is reflected in a smaller growth of RIF.

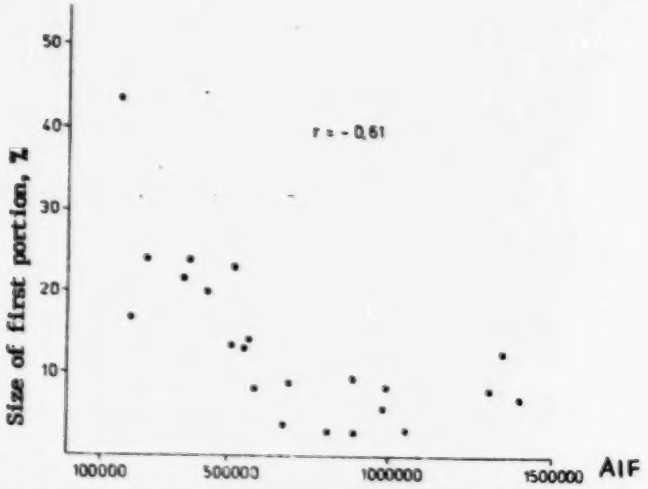

Fig. 2. Relationship between the size of the first batch of roe and absolute individual fecundity (AIF)

The maintenance of metabolic processes at a level ensuring normal physiological functioning of the body requires considerable expenditure of reserve substances when the efficiency of food utilization diminishes with age and the proportion of generative metabolism increases [13; 19]. The quality of the gonads is maintained at a level ensuring each egg the required amount of energy with age changes in metabolism by a simultaneous compensatory decrease in RIF from the age of (5+) 6 years. The necessity of a certain supply of energy for the gonads produced (according to our estimates, an average 7×10^{-4} J/egg) is also confirmed by the fact that the coefficient of variation of RIF is 4.3 times smaller than that of AIF. In females with gonads at the 4th-5th stages of maturity, we counted the number of hydrated oocytes, and calculated the size of the first portion of roe. It averaged 11% of the total number of eggs in the gonads. A comparison of the AIF value with the size of the first batch of roe revealed an inverse relationship, i.e r=-0.61 (Fig. 2). Therefore, as the mass and linear size of the spawners increase, we observe an increase in absolute individual fecundity (AIF); however, the physiological quality of the roe is maintained at the optimal level with age by means of a decrease in RIF on the one hand, and by a decrease in

the size of the first batch of roe on the other. One can, therefore, assume that the presence of a 2-stage mechanism ensures the necessary quality of the roe.

Table 4. Fecundity and physiological characteristics of the Baltic cod during different years

Characteristics	1976	1977	1978	1983	1984
Weighted average number of eggs per female	103,086	93,543	17,999	71,938	90,320
Population fecundity	20.9×10^{12}	17.5×10^{12}	1.63×10^{12}	17.3×10^{12}	33.0×10^{12}
Relative individual fecundity (RIF)	895	905	1051	511	888
Specific reserve of lipids in the body, g/kg	34	42	52	39	43
Energy content of one egg, Joules	3.6×10^{-4}	7.3×10^{-4}	7.1×10^{-4}	8.8×10^{-4}	9.2×10^{-4}
Energy reserve in roe of population (generative production), Joules	1.8×10^{10}	1.3×10^{10}	1.2×10^{9}	1.5×10^{10}	3.0×10^{10}
Survival of roe, %	14.3	12.6	13.9	8.4	11.3

Note: Survival of roe according to G.B. Grauman's published data [6] and unpublished data kindly supplied by the author himself.

We also attempted to determine the population fecundity of the cod and the energy equivalent of the roe spawned during different years (generative production). Judging by the data in table 4, the total quantity of eggs produced by the Baltic cod and, consequently, its generative production can vary significantly, in some cases more than 20-fold. The data derived are comparable to the values of population fecundity of the Barents Sea cod, which averages 74×10^{12} eggs [1].

The year 1976 was characterized by a very productive generation [3], which, in our opinion, was due to a number of factors. First of all, females constituted a large part of the spawners. The weighted average number of eggs per sexually mature female was also the highest (table 4). The parallellism noted by us in the dynamics of the lipid supply in

prespawning females and roe survival was upset in 1976, i.e. with a relatively low body supply of lipids, roe survival was at its highest. Apparently, the higher than usual survival rate of the eggs was in this case due to the favourable hydrologic conditions [22]. Therefore, the concurrence of the three above-mentioned factors with adequate larval feeding conditions [12] together promoted the appearance of an abundant generation despite the lowest level of lipids in the spawners.

The year 1978 was characterized by the smallest quantity of deposited eggs. Analysis of the data available to us indicates that the cause of the low population fecundity lay in the considerable decrease in the average age of the population [3]. There was also an increase in population density and a significant change in the sex ratio, the total number of females constituting 31% and the males 49% of the population in 1976. All of this led to a decrease in the weighted average number of eggs per sexually mature female cod and, consequently, reduced the population fecundity of the cod. At the same time, the relatively high reserve of lipids in the females contributed to a certain increase in RIF, but the energy reserve in one egg was the lowest in all the years of the investigation.

The maximum value of population fecundity was recorded in 1984. This was apparently due to the aging of the brood stock [3] and to the highest number of female spawners.

Summary

1. The absolute individual fecundity (AIF) of the Baltic cod varies from 200,000 to 2,000,000 eggs.

2. The energy of the oogenetic processes in the cod of the eastern part of the Baltic Sea is greater than in other geographic regions, which manifests itself in a greater growth of fecundity with an increase in the mass of the females, and is due to the variable conditions on the outskirts of the species range.

3. The relative individual fecundity (RIF) reflects the specificity of the energy of the developing eggs more clearly than the absolute individual fecundity.

4. Our results give grounds for assuming that a 2-stage mechanism provides for the optimal quality of the spawned roe, controlling both the

value of relative individual fecundity, and the quantity of roe in the first batch.

5. During the study period, the population fecundity of the Baltic cod varied from 1.63×10^{12} to 33.0×10^{12} eggs, and generative production from 1.2×10^{9} to 3.0×10^{10} Joules.

References

1. Aldonov V.K., Borisov V.M., Serebryakov V.P. Population fecundity of Arctic-Norwegian cod. Rybnoye khoz., 1983, No. 1, p. 33-34.

2. Anokhina L.Ye. Tendencies of fecundity changes in fish, based on the example of spring- and autumn-spawning Baltic herring. Moscow, "Nauka" Publishers, 1969.

3. Baranova T.D. Some parameters of the E Baltic cod population in subareas 26 and 28, as related to the population dynamics. Fisch.-Forsch., Rostock 24 (1986) 2, p. 55-59.

4. Bogoyavlenskaya M.P. Physiologic-biochemical characteristics of North Sea cod. Trudy VNIRO, 1977, v. 121, p. 73-81.

5. Gosh R.I., Zhukinsky V.N. Effect of female age on the energy metabolism of oocytes and ova in "taran". Summaries of reports presented at the All-Union Conference on Ecological Physiology of Fish. Moscow, 1973, p. 200-202.

6. Grauman G.B. Method of predicting the recruitment of the Baltic cod three years in advance. IN: Assessment of Commercial Fish Stocks and Prediction of Catches. Moscow, 1980, p. 91-97.

7. Ivlev V.S. Method of determining population fecundity in fish. Trudy Latv. otd. VNIRO, 1953, No. 1, p. 37-41.

8. Johansen B.P. Fecundity in fish and the factors determining it. Vopr. ikhtiol., 1955, No. 3, p. 57-68.

9. Ipatov V.V. Dynamics of the nucleic acid content in the tissues of the Baltic cod as an indicator of the intensity of growth processes. IN: Fishery Research in the Baltic Sea Basin. Riga, Avots, 1981, No. 17, p. 107-112.

10. Krivobok M.N., Takareva G.I. Weight dynamics of the body and individual organs in the Baltic cod during maturation of the gonads. Trudy VNIRO, 1972, v. 85, No. 3, p. 46-55.

11. Kushing D.Kh. Marine Ecology and Fishery. Moscow, "Pishch. prom.", 1979.

12. Line R.Ya., Sidrevits L.L. Yearly changes in the quantity and species composition of the zooplankton in the Baltic Sea. IN: Problems of Research and Mathematical Modelling of the Ecosystem of the Baltic Sea. "Baltika" Project, Leningrad, Gidrometeoizdat, 1984, No. 2, p. 129-136.

13. Lipsakaya N.Ya. Uzars D.V., Chekunova V.I., Shatunovsky M.I. Some features of energy metabolism in the Baltic cod (*Gadus morhua callarias* L.). Trudy VNIRO, 1972, v. 85, No. 3, p. 81-85.

14. Nikolsky G.V. Fish Ecology. Moscow, Vysshaya shkola, 1974.

15. Nikolsky G.V. Theory of the Population Dynamics of Fish. Moscow, Pishch. prom., 1974.

16. Pavlovskaya R.M. Some questions concerning the biology of reproduction and development in the Black Sea anchovy, as related to the question of population dynamics. Trudy AzcherNIRO, 1958, No. 16, p. 75-109.

17. Peslak Ya.K. Relationship between the morphophysiological characteristics of the Baltic salmon and the quality of the progeny during artificial breeding. Author's abstract of dissertation for the degree of Candidate of Biological Sciences. Moscow, 1973.

18. Sorokin V.P. Oogenesis and the sexual cycle in cod (*Gadus morhua morhua* L.). Trudy PINRO, 1957, No. 10, p. 125-144.

19. Shatunovsky M.I. Ecological Tendencies of Metabolism in Sea Fish. Moscow, "Nauka", 1980.

20. Shevchenko V.V., Shatunovsky M.I. On the fecundity of the North Sea haddock. Trudy VNIRO, 1977, v. 121, p. 110-113.

21. Shirokova M.Ya. Gametogenesis and the structure of the spawning population of the Baltic cod. Author's abstract of dissertation for the degree of Candidate of Biological Sciences, Kaliningrad, 1971.

22. Kaleis M., Yula E. Peculiarities of hydrographic conditions in the Baltic in 1975 and 1976. Annales biol., 1978, v. XXXIII.

23. Kjorsvik E., Lonning S. Effects of egg quality on normal fertilization and early development of the cod, *Gadus morhua* L. J. Fish. Biol. 1983, No. 23, p. 1-12.

24. Lowry O.H., Rosebrough N.J., Farr A.J., Randall R.J. Protein measurement with the folin phenol reagent. J. Biol. Chem., 1951, v. 193, No. 1, p. 265-273.

25. Oosthuizen E., Daan N. Egg fecundity and maturity of North Sea cod, *Gadus morhua*. Netherlands Journal of Sea Research, 1974, v. 8, No. 4, p. 378-397.

26. Folch J., Ascoli I., Lees M., Meed I., le Bron F.N. Preparation of lipid extracts from brain tissue. J. Biol. Chem., 1951, v. 191, No. 2.

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